Q2 - A National 'unofficial' Testbed for QPE

Ken Howard
HydroMet Research Group
NSSL

Radar-Rainfall

RADAR-RAINFALL UNCERTAINTIES

Where are We after Thirty Years of Effort?

BY WITOLD F. KRAJEWSKI, GABRIELE VILLARINI, AND JAMES A. SMITH

Now is a good time to assess three decades of progress since Jim Wilson and Ed Brandes summarized the operational capability of radar to provide quantitative rainfall estimates with potential applications to hydrology.

The purpose of this article is to honor Jim Wilson and Ed Brandes for their seminal paper (Wilson and Brandes 1979), "Radar measurement of rainfall—A summary." The work has been frequently cited [163 times according to the Institute for Scientific Information (ISI) Web of Knowledge as of 7 June 2009], and it was a comprehensive attempt to summarize the capabilities of weather radar to provide quantitative estimates of precipitation, which inspired a generation of radar hydrometeorologists in the United States and elsewhere. They discussed the numerous sources of uncertainties associated with radar-based rainfall estimates, including calibration, attenuation, bright band, anomalous propagation, beam blockage, ground clutter and spurious returns, random errors, and variability in the relation between reflectivity Z and rainfall rate R (Z–R relations). The authors also addressed the possible impact of the errors in rain gauge measurements of rainfall and sampling uncertainties (errors resulting from the approximation of an areal estimate using a point measurement). In particular, based on contemporary research (e.g., Huff 1970; Woodley et al. 1975) concerning the spatial sampling error, Wilson and Brandes (1979) reported that it "decreases with increasing area size, increasing time period, increasing gage density, and increasing rainfall amount." Based on more recent research, we have developed quantitative models that reflect how the spatial sampling errors decrease with increasing temporal and decreasing spatial scales, rain gauge network density, and rainfall amount (e.g., Ciach and Krajewski 1999; Zhang et al. 2007; Villarini et al. 2008; Villarini and Krajewski 2008).

These uncertainties notwithstanding, Wilson and Brandes foresaw the operational utility of radar-rainfall estimation and promoted its use in flash flood forecasting, noting that "radar can be of lifesaving usefulness by alerting forecasters to the potential for flash flooding."

In this article, rather than trying to review the (sizable) literature of the different methods of radar-rainfall estimation and their accompanying sources of uncertainties, our goal is to answer the question, How much better can we do now versus what was done 30 yr ago? To answer this question, we replicate,

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The abstract for this article can be found in this issue, following the table of contents.

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In final form 7 September 2009

"Despite over 30 yr of effort, the comprehensive characterization of uncertainty of radar-rainfall estimation has not been achieved."

Q2 Vision

*"While tremendous progress has been made in the last quarter-century in many areas of QPE and VSTQPF, **significant gaps continue to exist in both knowledge and capabilities** that are necessary to produce **accurate high-resolution precipitation estimates at the national scale** for a wide spectrum of users."*

*"To meet the nation's needs for the precipitation information effectively, the authors herein propose a community-wide **integrated approach for precipitation information that fully capitalizes on recent advances in science and technology, and leverages the wide range of expertise and experience that exists in the research and operational communities.** "*

ARTICLES

IMPROVING QPE AND VERY SHORT TERM QPF

An Initiative for a Community-Wide Integrated Approach

BY STEVEN V. VASILOFF, DONG-JUN SEO, KENNETH W. HOWARD, JIAN ZHANG, DAVID H. KITZMILLER, MARY G. MULLUSKY, WITOLD F. KRAJEWSKI, EDWARD A. BRANDES, ROBERT M. RABIN, DANIEL S. BERKOWITZ, HAROLD E. BROOKS, JOHN A. MCGINLEY, ROBERT J. KULIGOWSKI, AND BARBARA G. BROWN

A multisensor applications development and evaluation system at the National Severe Storms Laboratory addresses significant gaps in both our knowledge and capabilities for accurate high-resolution precipitation estimates at the national scale.

Water is a precious resource and, when excessive or in short supply, a source of many hazards. It is essential to monitor and predict water-related hazards, such as floods, droughts, debris flows, and water quality, and to determine current and future availability of water resources. Accurate quantitative precipitation estimates (QPE) and very short term quantitative precipitation forecasts (VSTQPF) provide key input to these assessments. [QPE and VSTQPF are hereafter referred to collectively as quantitative precipitation information (QPI).] To meet these needs at the national scale, accurate QPI is needed at various temporal and spatial scales for the entire United States, its territories, and immediate surrounding areas. Temporal scales range from minutes to several hours for flash flood prediction. QPI products can then be aggregated to support longer-term applications for water supply prediction. Spatial scales range from a few square kilometers or less for urban flash flood prediction,

AFFILIATIONS: VASILOFF, HOWARD, RABIN, AND BROOKS—NOAA/National Severe Storms Laboratory, Norman, Oklahoma; SEO—NOAA/NWS/Office of Hydrologic Development, Silver Spring, Maryland, and University Corporation for Atmospheric Research, Boulder, Colorado; ZHANG—Cooperative Institute for Mesoscale Meteorological Studies, University of Oklahoma, and NOAA/OAR National Severe Storms Laboratory, Norman, Oklahoma; KITZMILLER—NOAA/NWS/Office of Hydrologic Development, Silver Spring, Maryland; MULLUSKY—NOAA/NWS/Office of Climate, Water, and Weather Services, Silver Spring, Maryland; KRAJEWSKI—IIHR—The University of Iowa, Iowa City, Iowa; BRANDES AND BROWN—National Center for Atmospheric Research, Boulder, Colorado; BERKOWITZ—NOAA/WSR-88D Radar Operations Center, Norman, Oklahoma; MCGINLEY—NOAA/Earth System Research Laboratory, Boulder, Colorado; KULIGOWSKI—NOAA/National Environmental Satellite, Data, and Information Service, Camp Springs, Maryland
CORRESPONDING AUTHOR: Steven Vasiloff, NOAA/National Severe Storms Laboratory, National Weather Center, 120 David L. Boren Blvd., Norman, OK 73072
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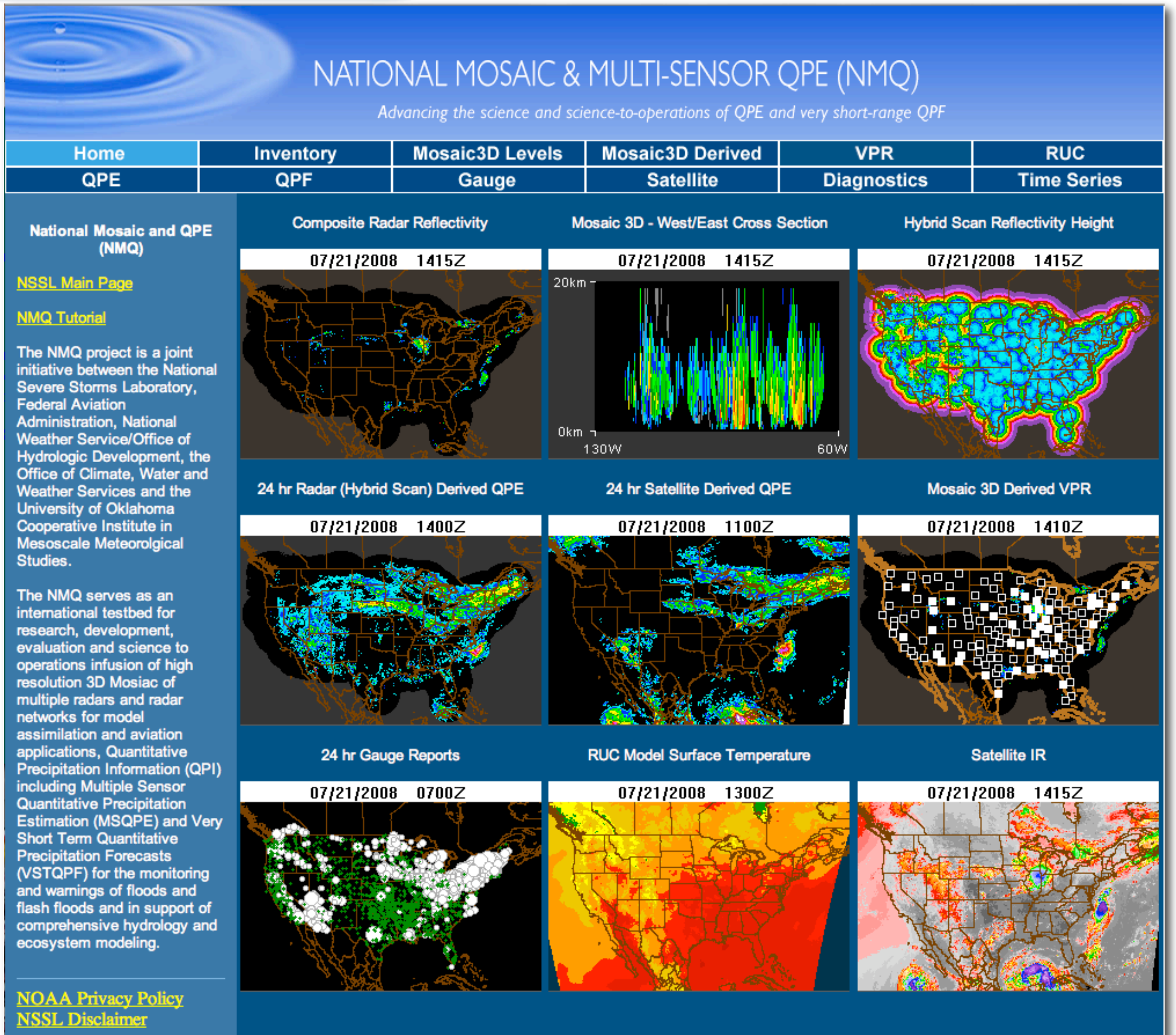
Q2 Implementation

Q2 <u>exists today</u> as a scientific and community-based convergence towards accurate, very high-resolution **multi-radar, multi-sensor (MRMS)** precipitation estimates on a national scale.

Q2 goal is to glean the best science practices and techniques from NOAA's River Forecast Centers, Forecast Offices, Office of Hydrology, domestic/international organizations, universities **and Testbeds (HMT)**.

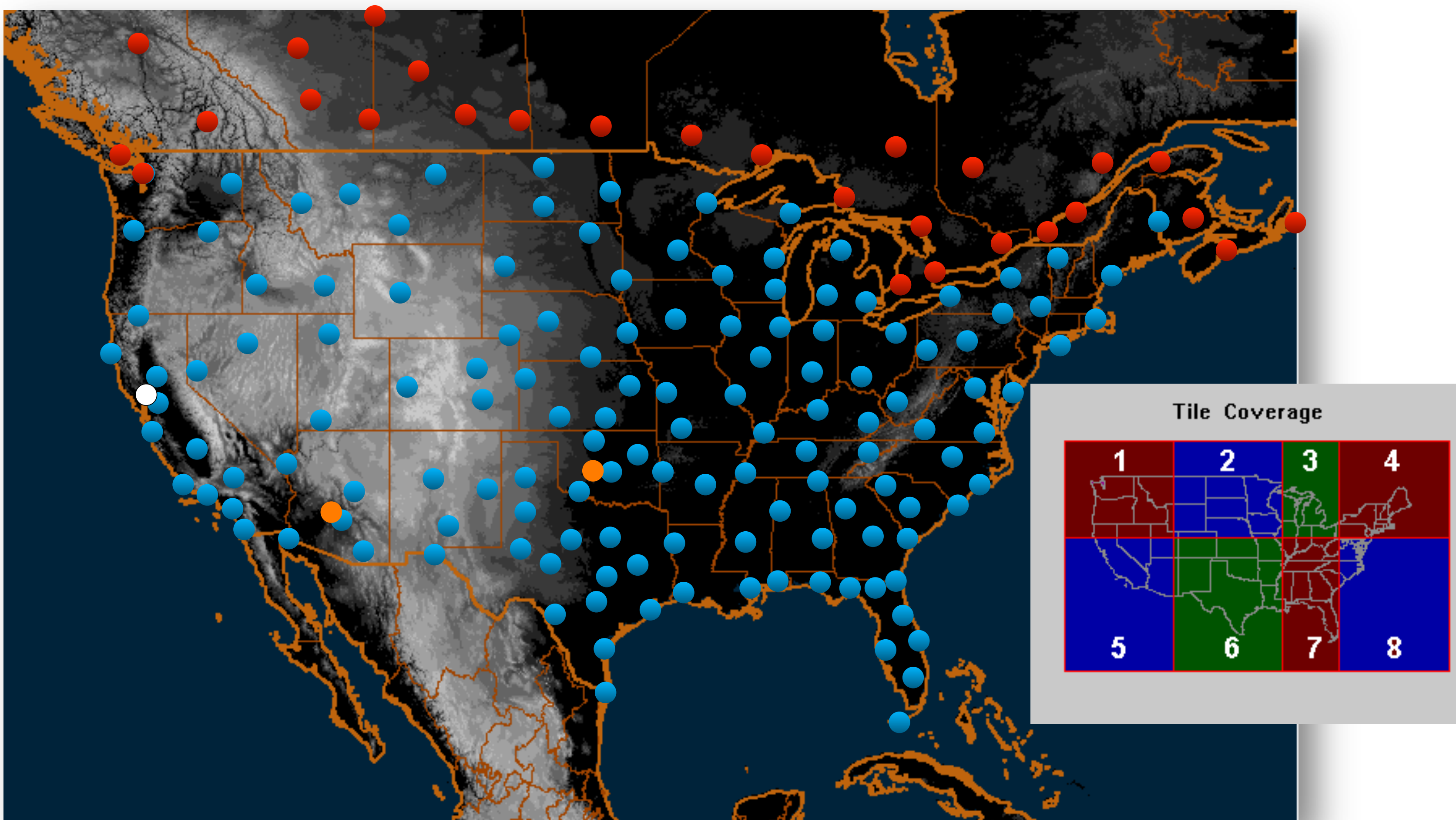
Q2

Real time platform to develop, test, and assess advance techniques in quality control, data integration and precipitation estimation and short term forecasting.



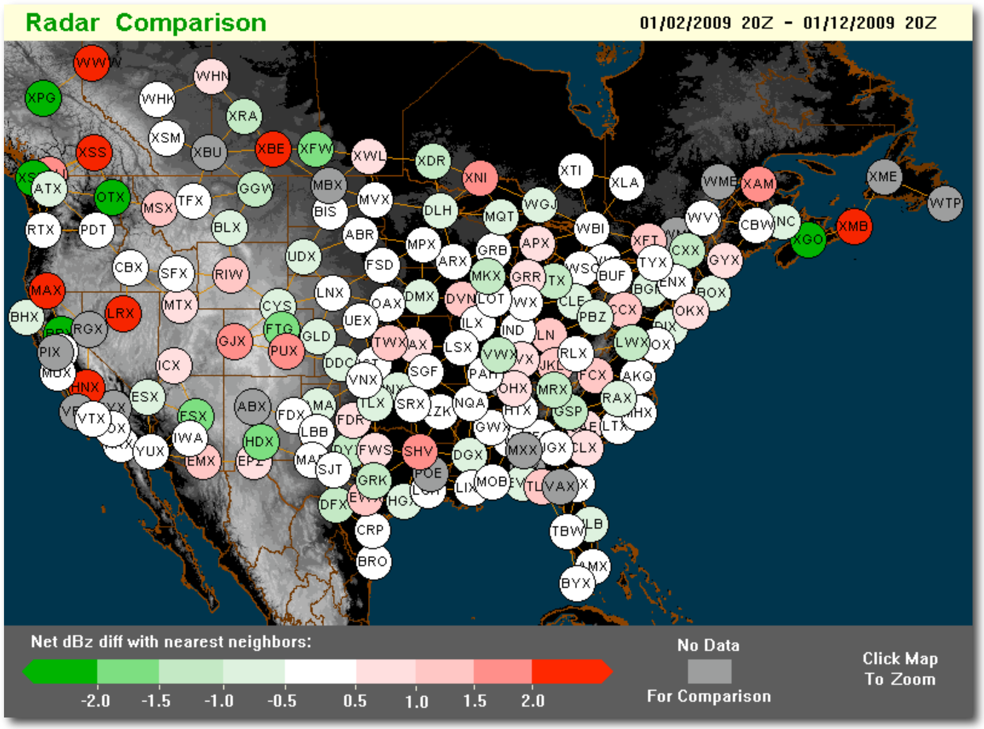
http://nmq.ou.edu

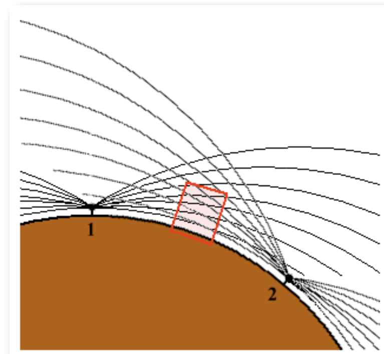
Q2 Domain

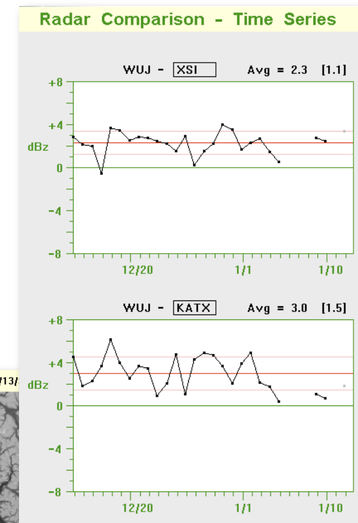


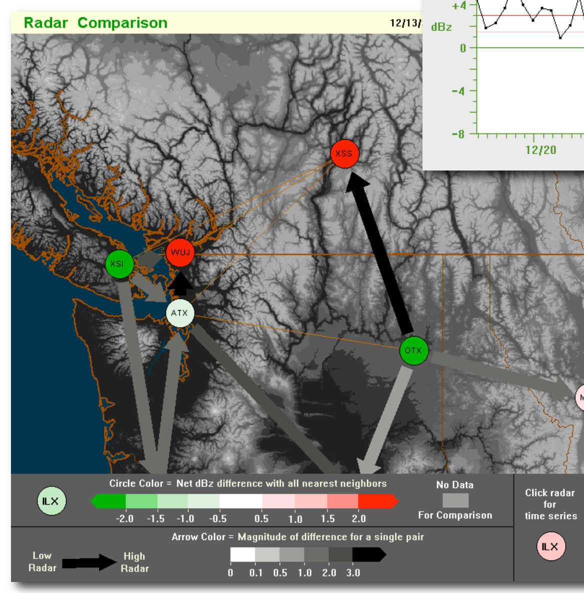
● ~140 WSR-88D ● 31 Canadian ● 2 TDWR ○ 1 TV station radar

Radar Reflectivity Comparison Tool (RRCT)





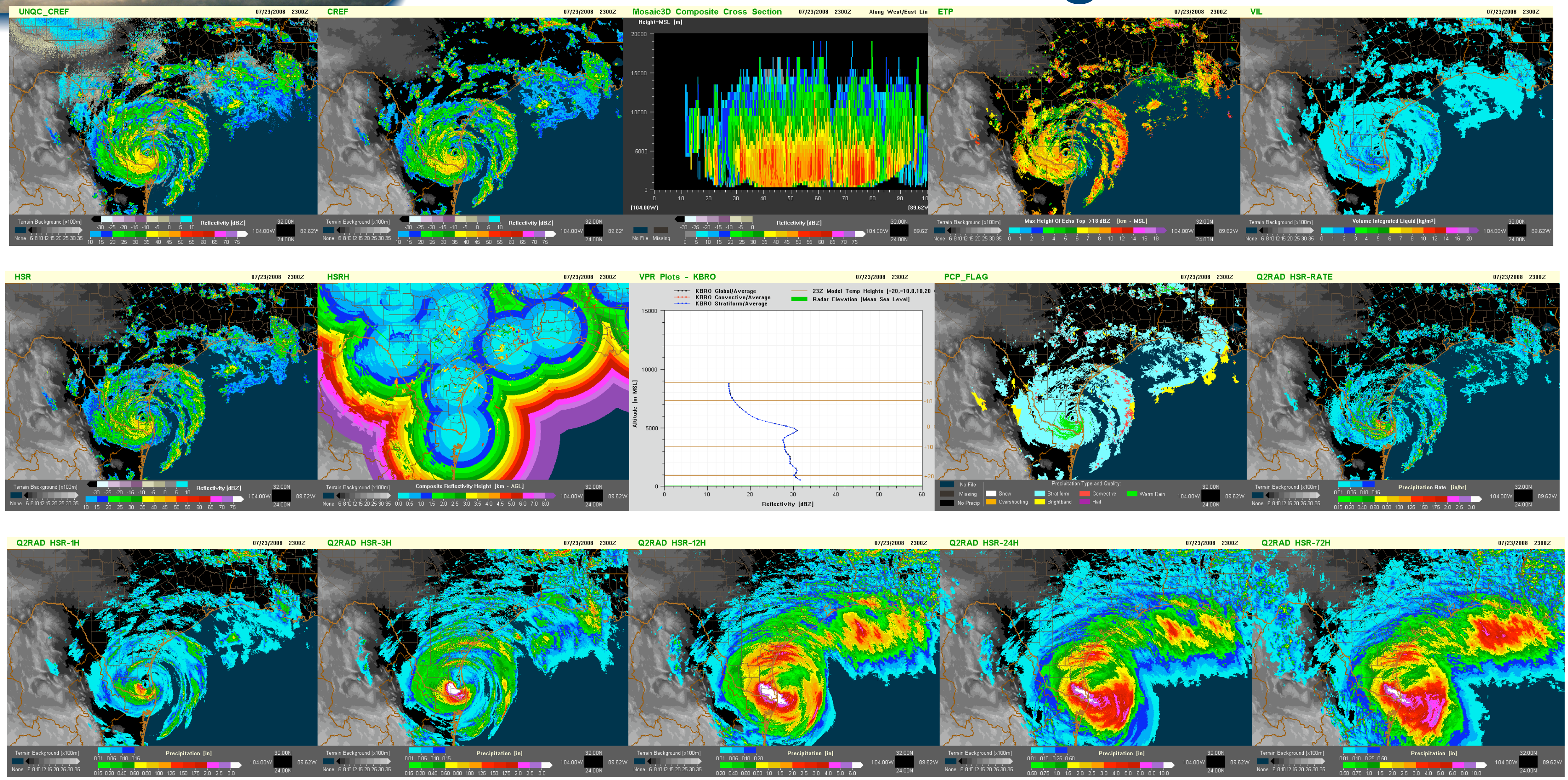




Objective: A real time system to monitor the quality of base level data to determine potential calibration offsets and transmitter drift.

NOAA's National Weather Service
Radar Operations Center
NEXRAD WSR-88D

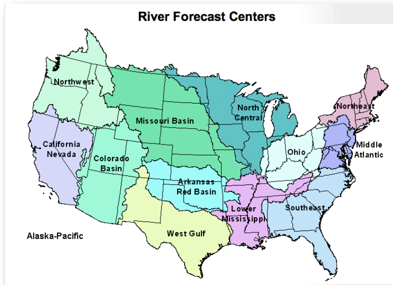
Q2 Precipitation & Diagnostic Grids



NSSL produces and disseminates a suite of **60+** high resolution product grids over North America **(1-km, 5-minutes)** for use in model data assimilation, aviation product development and hydrometeorology.

Q2 Collaborators

NCEP — National Centers for Environmental Prediction



NOAA's National Weather Service
Radar Operations Center
NEXRAD WSR-88D

National Weather Service
National Operational Hydrologic Remote Sensing Center

Environment Canada / Environnement Canada

Unidata

NCAR

UCAR

NASA

USGS science for a changing world

Q2 Precipitation Products And Diagnostics

Central Weather Bureau

WRA

SRP *Salt River Project*

Stand Alone Q2 System

NOAA's National Weather Service
Advanced Hydrologic Prediction Service

NOAA's National Weather Service
Office of Hydrologic Development

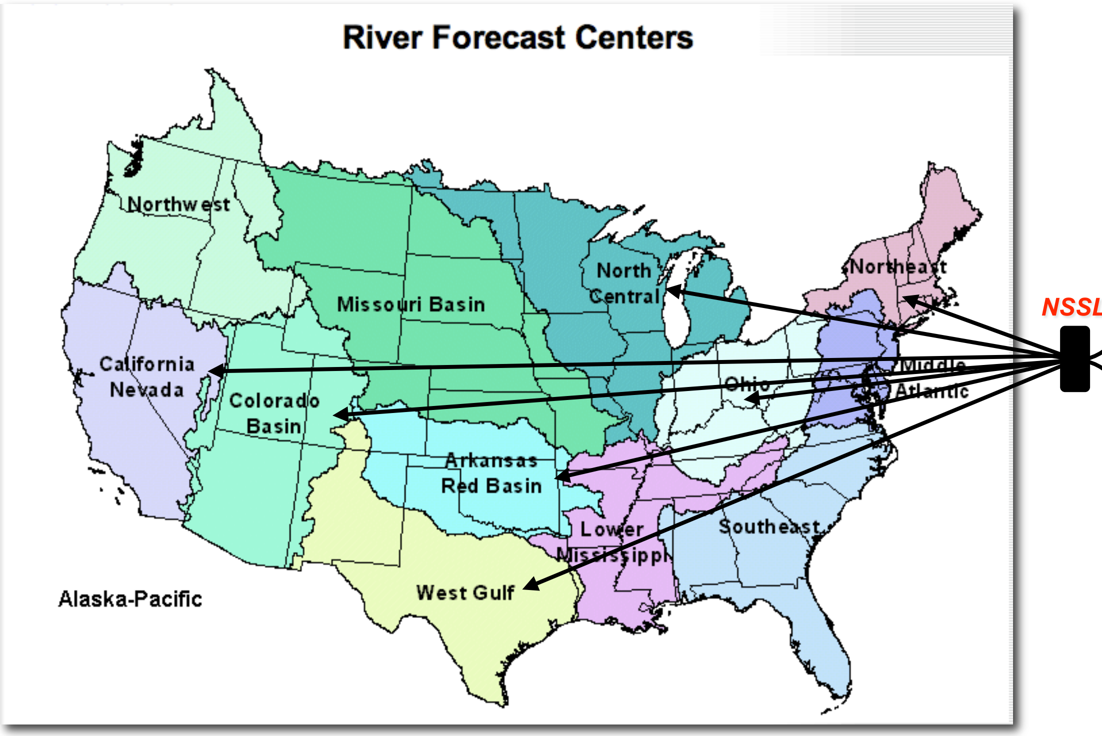
NOAA's National Weather Service
Office of Climate, Water, and Weather Services

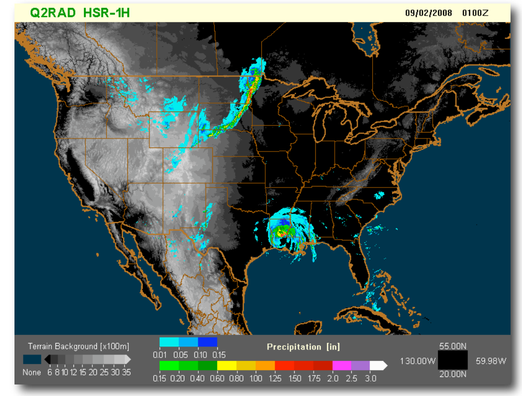
Earth System Research Laboratory
Serving Society through Science

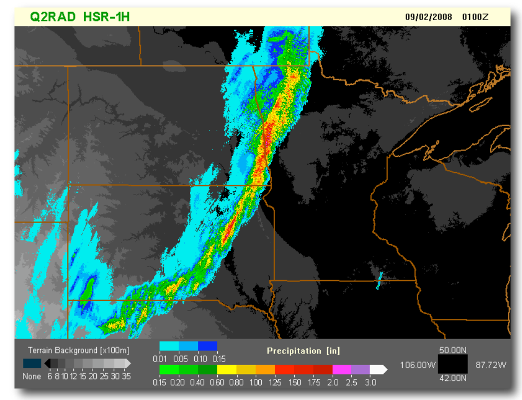
National Oceanic and Atmospheric Administration
Great Lakes Environmental Research Laboratory

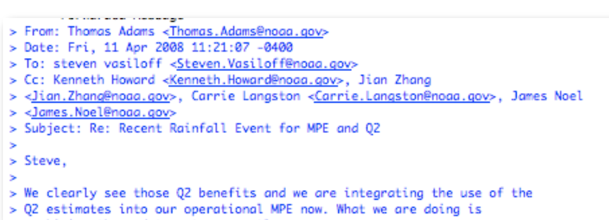
National Oceanic and Atmospheric Administration
Hydrometeorology Testbed Program

Interactions with River Forecast Centers









> From: Thomas Adams <Thomas.Adams@noaa.gov>
> Date: Fri, 11 Apr 2008 11:21:07 -0400
> To: steven vasiloff <Steven.Vasiloff@noaa.gov>
> Cc: Kenneth Howard <Kenneth.Howard@noaa.gov>, Jian Zhang
> <Jian.Zhang@noaa.gov>, Carrie Langston <Carrie.Langston@noaa.gov>, James Noel
> <James.Noel@noaa.gov>
> Subject: Re: Recent Rainfall Event for MPE and Q2
>
> Steve,
>
> We clearly see those Q2 benefits and we are integrating the use of the
> Q2 estimates into our operational MPE now. What we are doing is

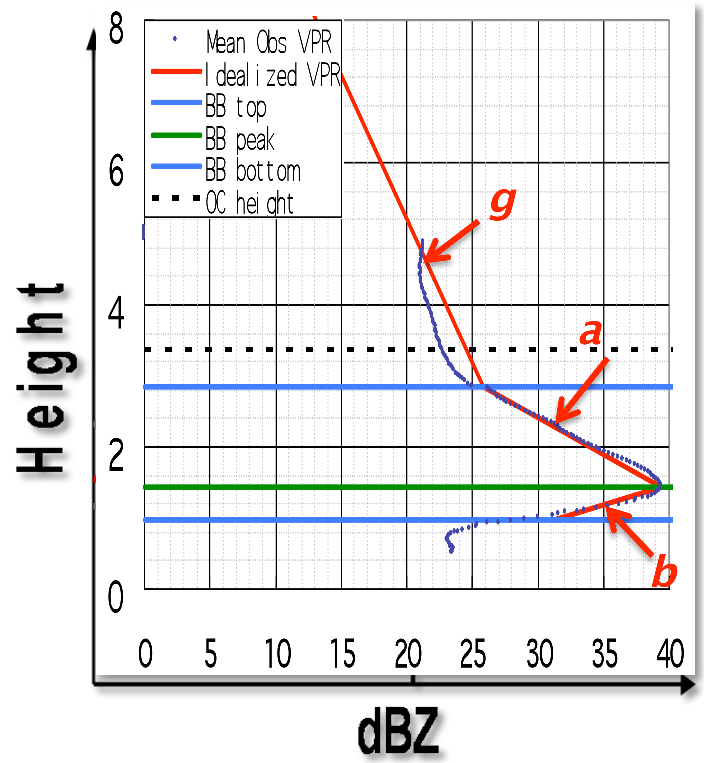
NSSL researchers receive feed back, comments and ideas from the operational personal, private sector and other researchers to improve the quality and accuracy of the precipitation estimates.

HMT West Methodologies to 'real time' Products

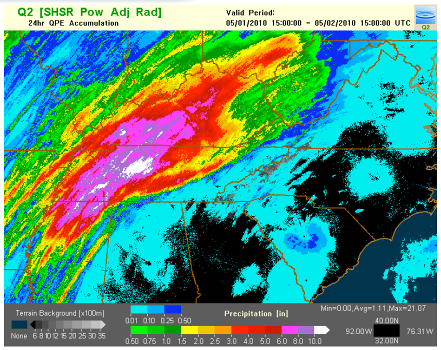
Developed a new suite of QPE products and radar diagnostics based upon a detailed analysis of HMT IOPs and effective cross agency scientific dialog (no egos, no intuitional bias, no counting publications, no drama).

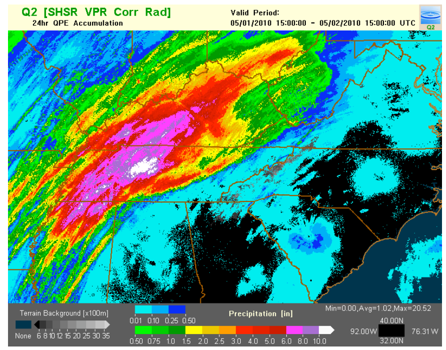
The development of new methodologies and techniques based on HMT domain and scientific insight has evolved to a national domain for further testing and evaluation.

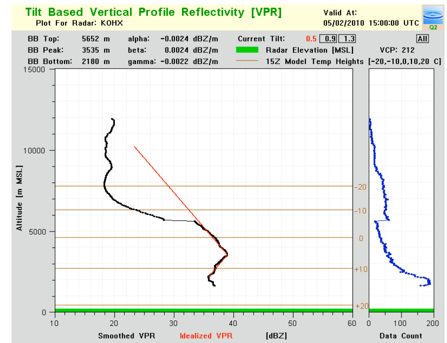
New methodologies and products are accessible to the RFCs for use and assessment in operations.

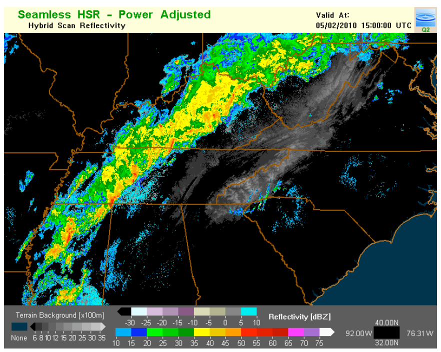


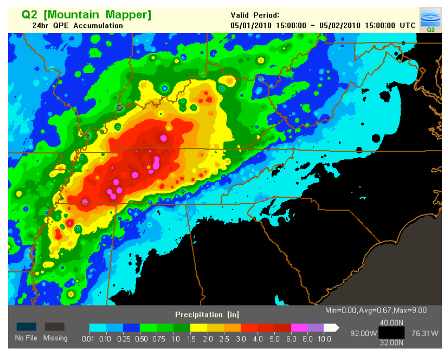
HMT Collaboration
New Products and Diagnostics

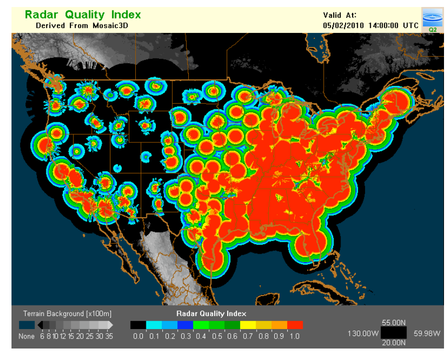


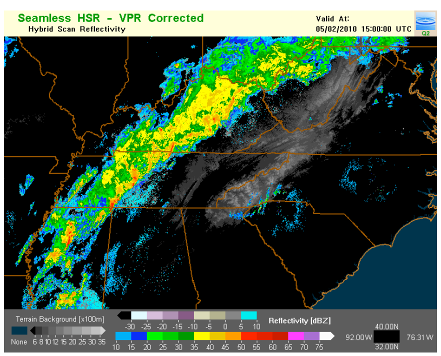


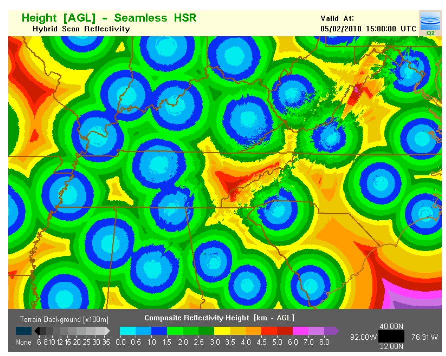


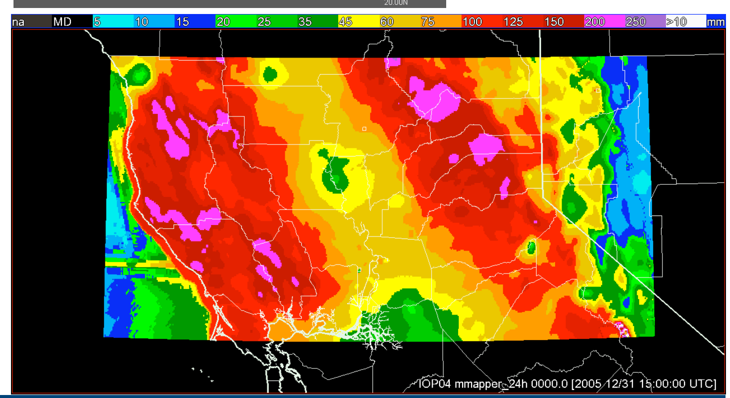




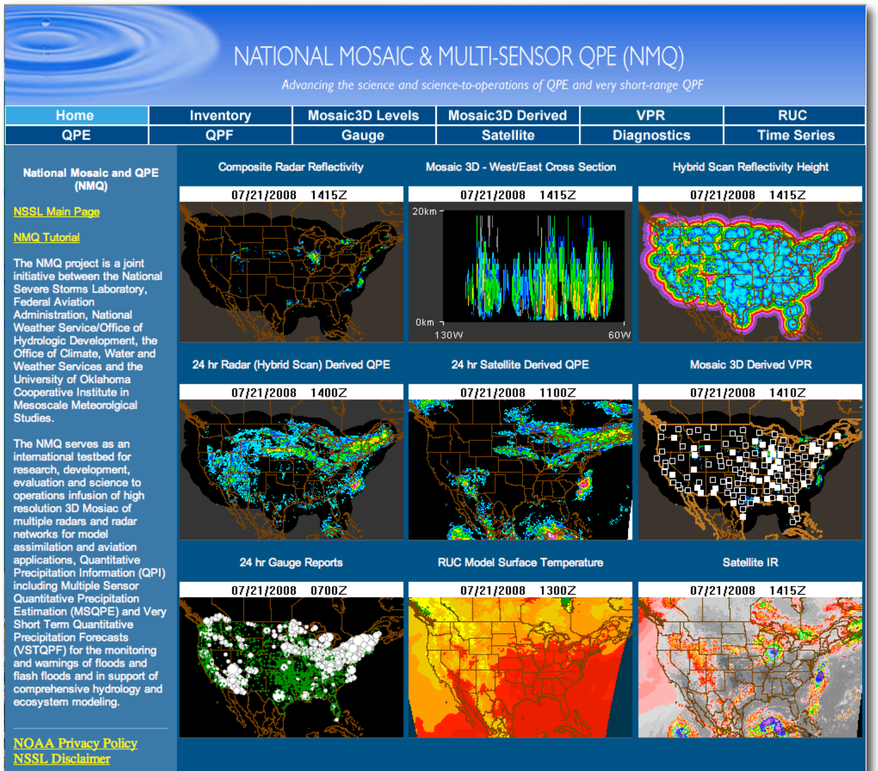


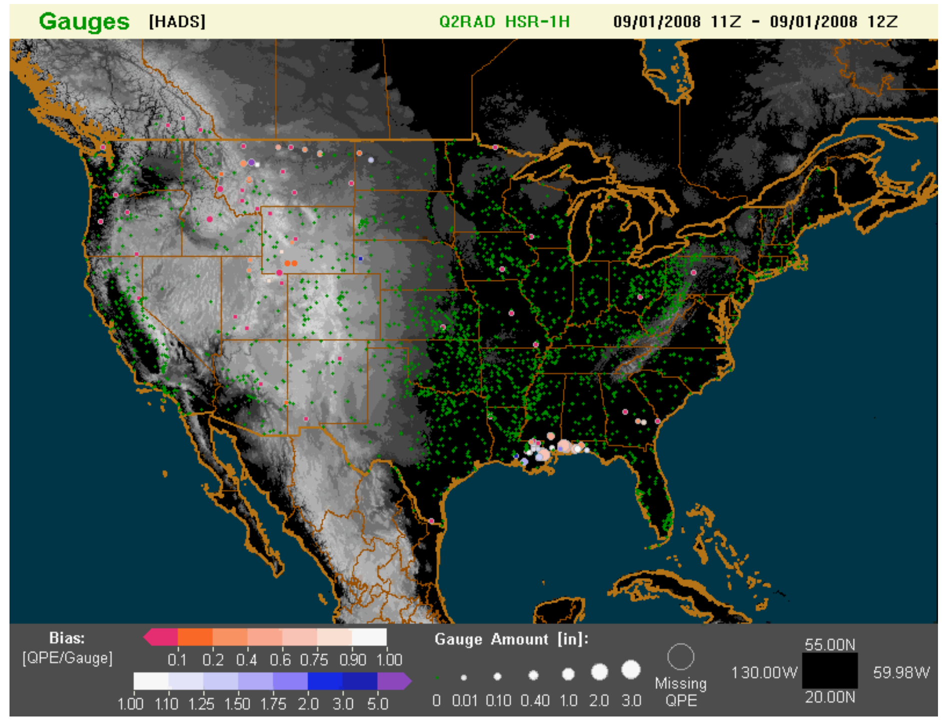






Verification - QVS



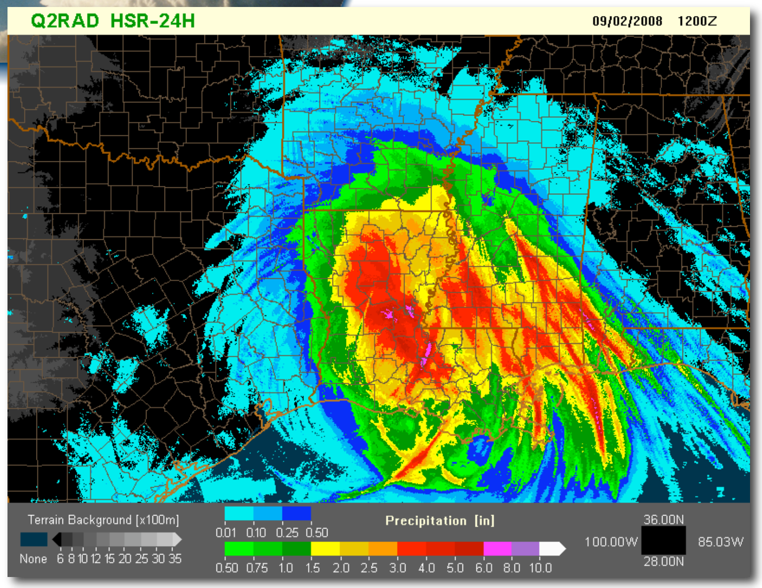


Loop

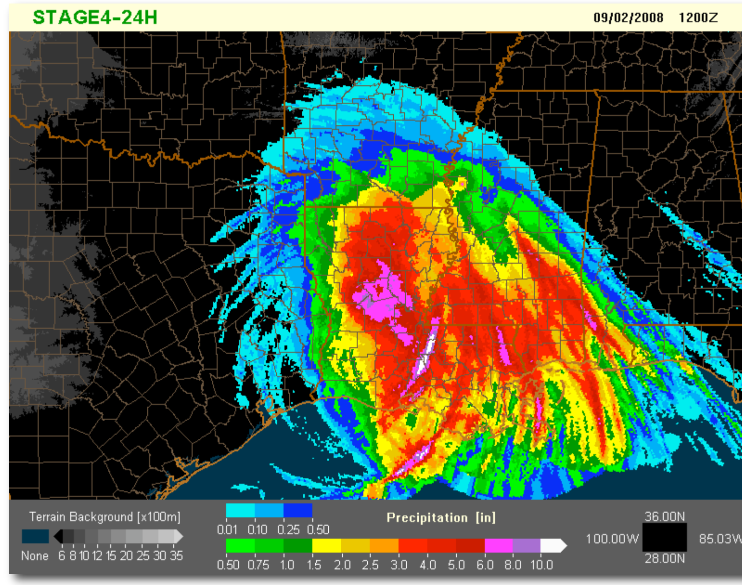
NSSL researchers and collaborators can assess and compare the quality of the precipitation estimates using a spectrum of independent observing networks and techniques.

Verification

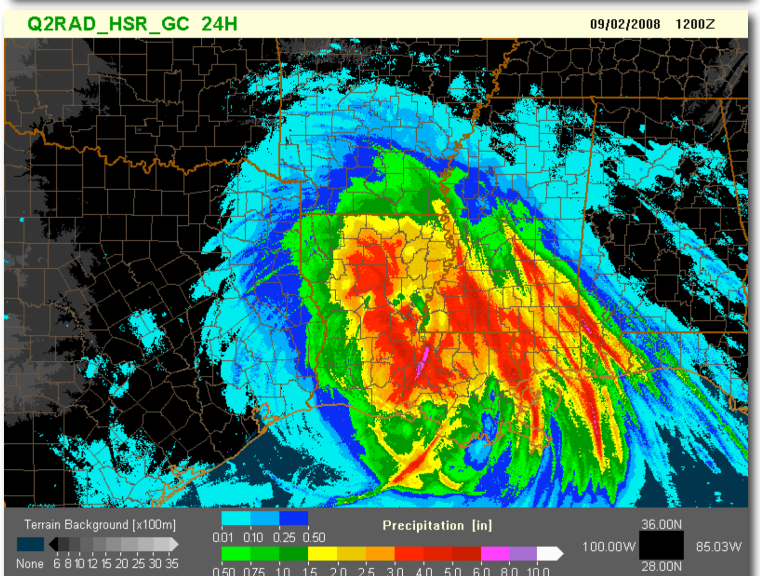
Q2 Radar Only



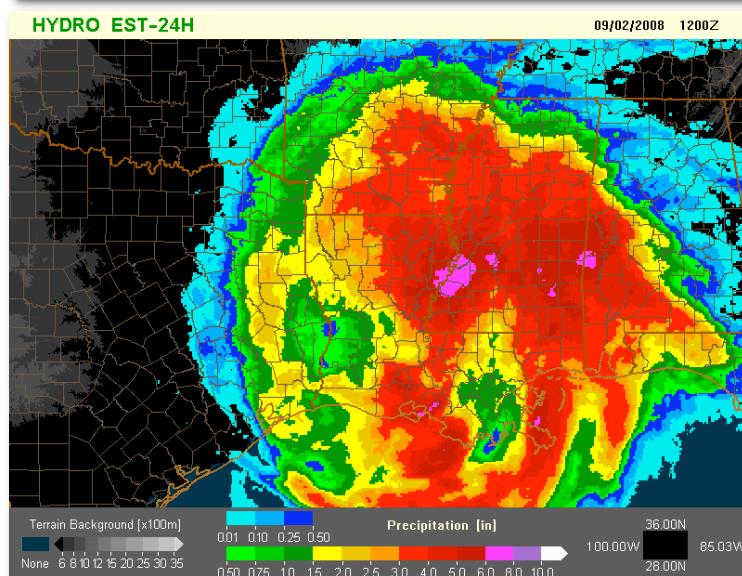
NWS RFC Stage 4



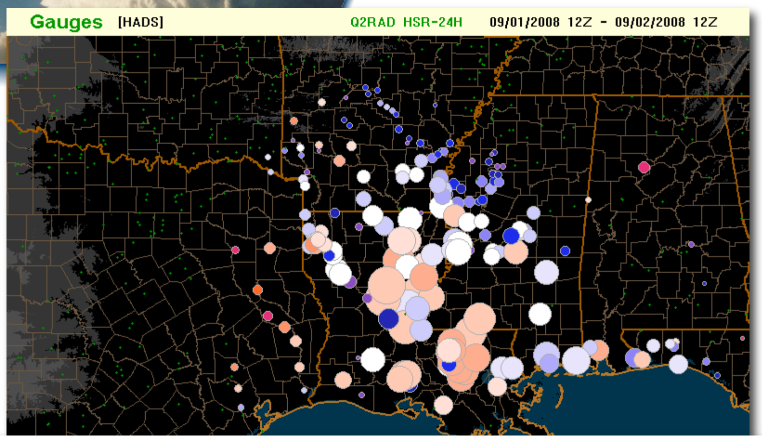
Q2 Gauge Correct

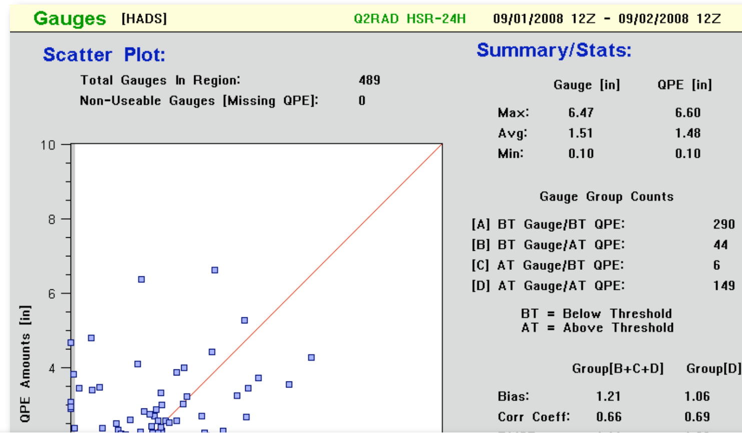


NESDIS HydroEst

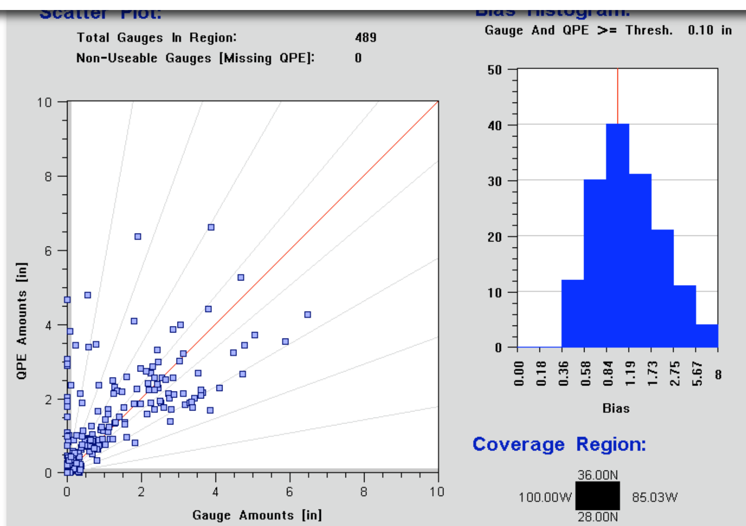


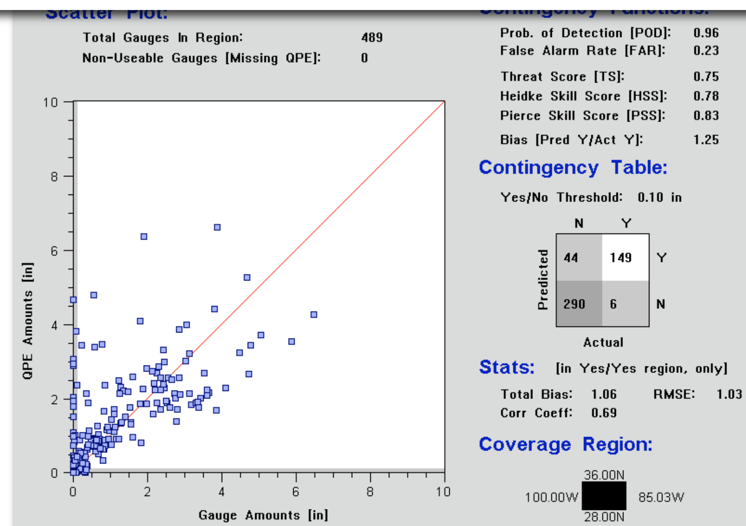
Verification



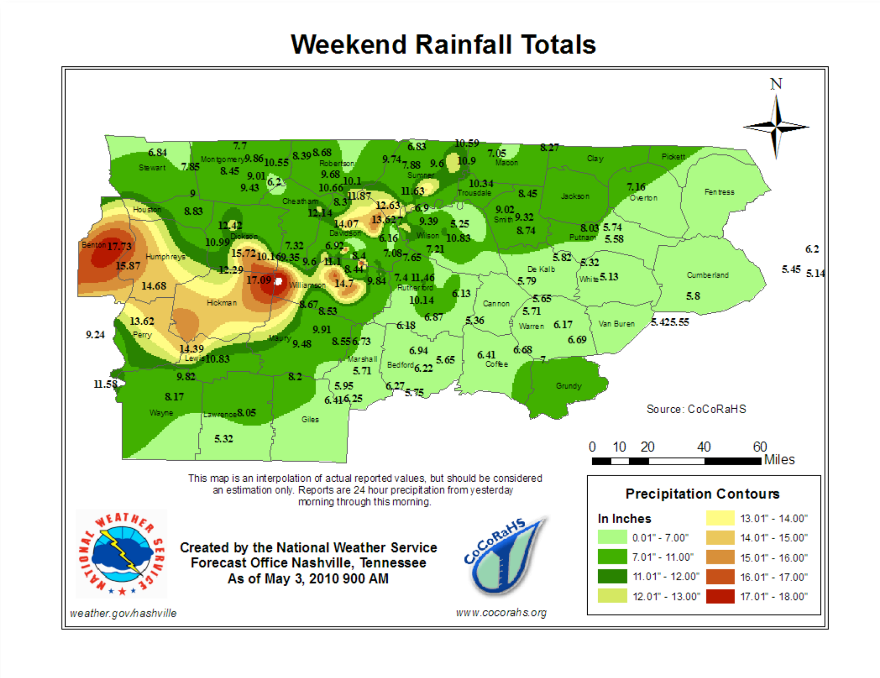


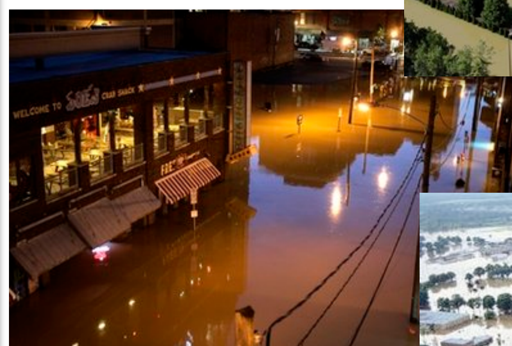
On a daily basis we verify 7600+ MRMS QPE /gauge pairs



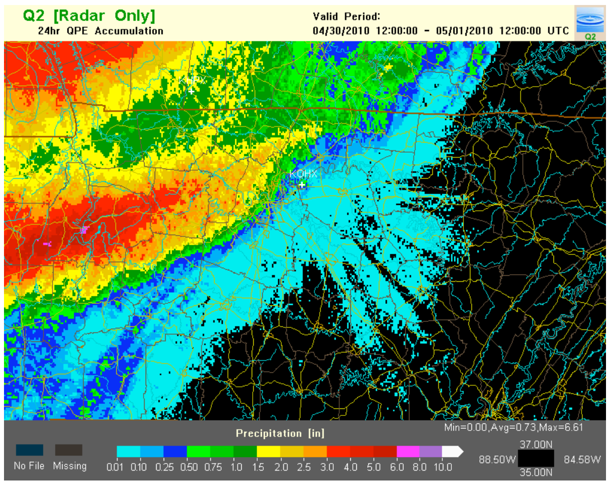


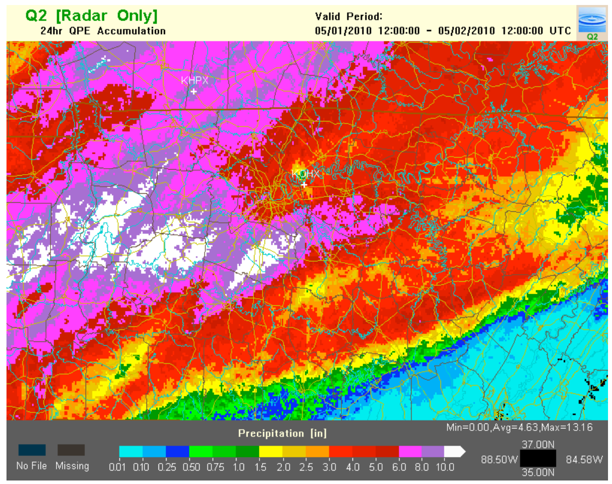
Tennessee Flood Event

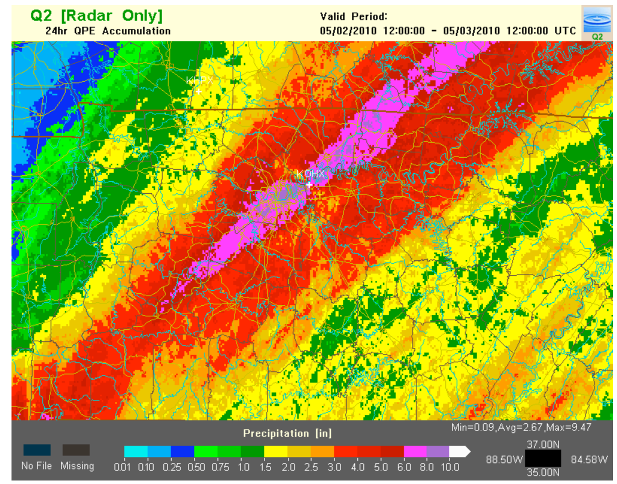


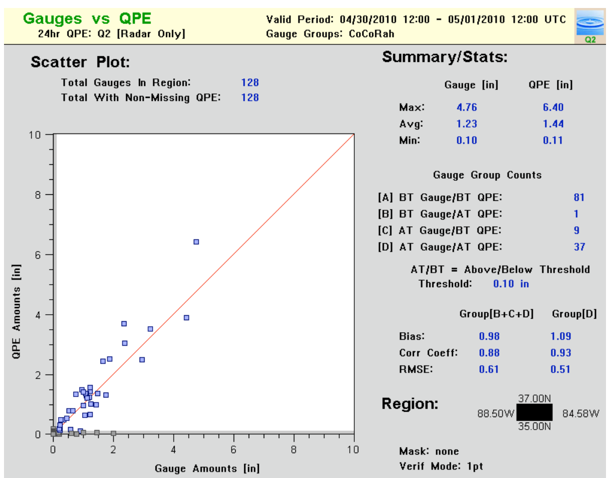


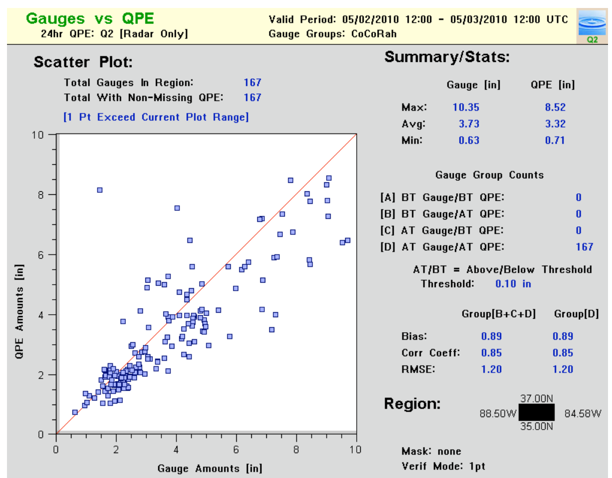
Q2
Technique Performance

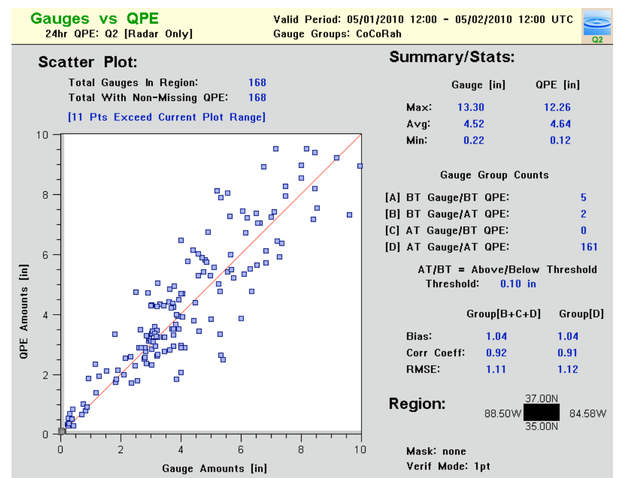




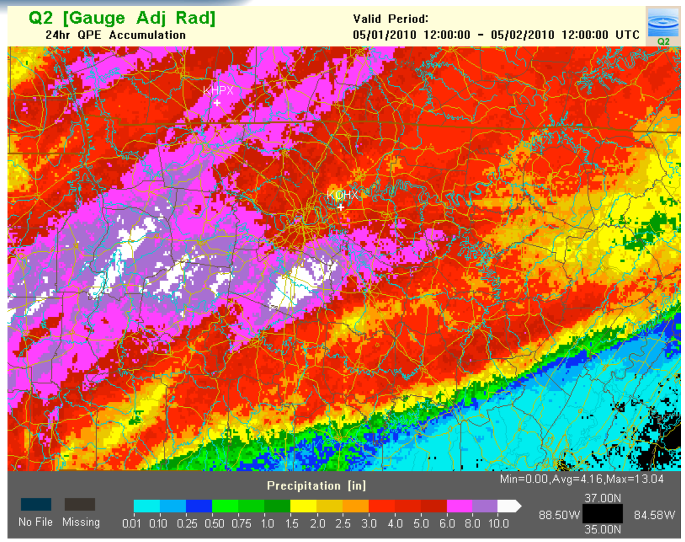


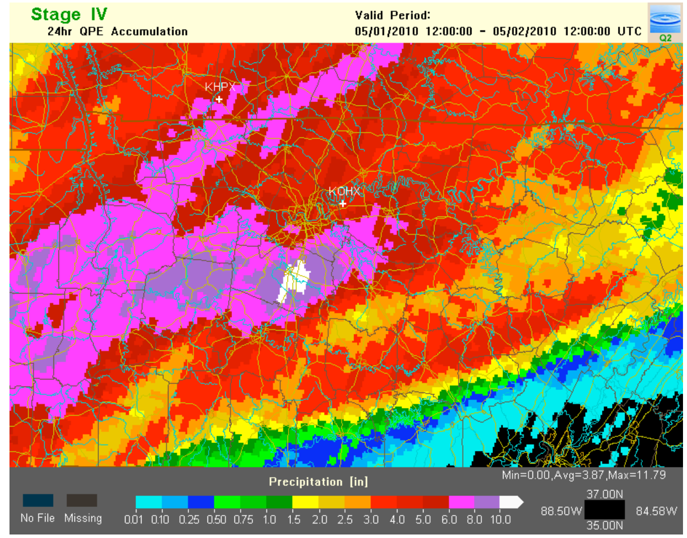


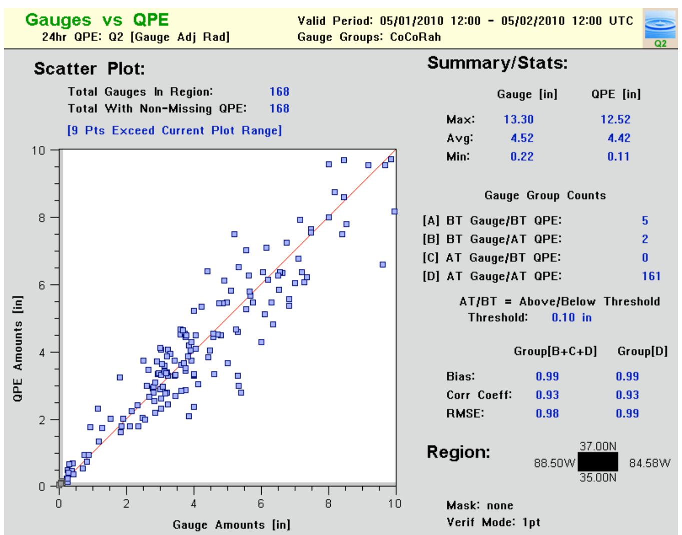


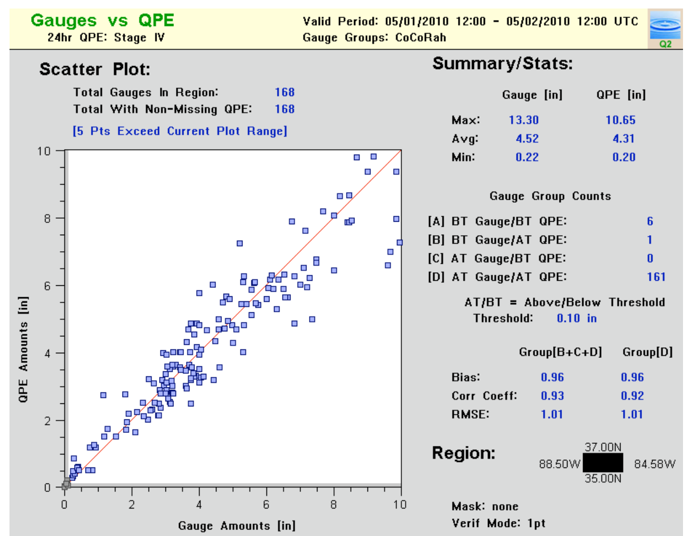


Q2 vs. Stage 4

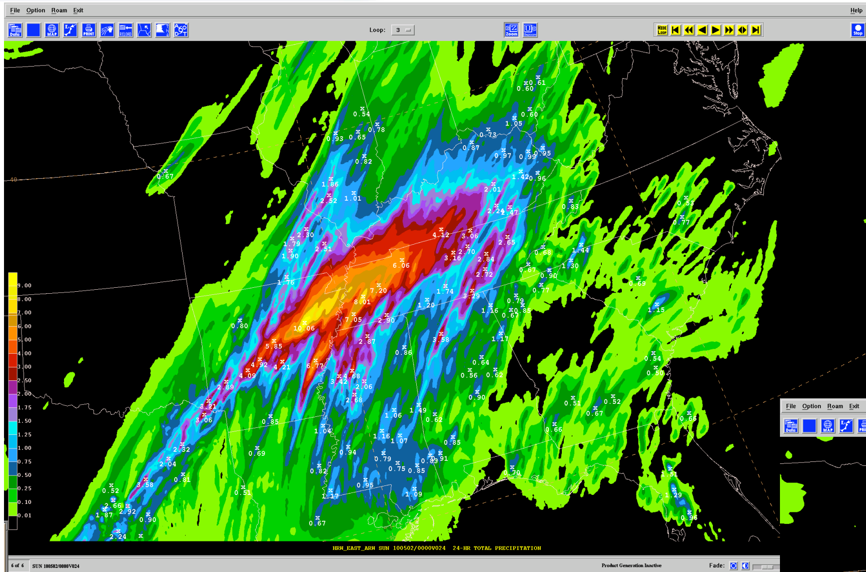

Q2 [Gauge Adj Rad]
24hr QPE Accumulation
Valid Period:
05/01/2010 12:00:00 - 05/02/2010 12:00:00 UTC
KHPX
KOHX
Precipitation [in]
Min=0.00,Avg=4.16,Max=13.04
No File Missing
0.01 0.10 0.25 0.50 0.75 1.0 1.5 2.0 2.5 3.0 4.0 5.0 6.0 8.0 10.0
37.00N
88.50W
84.58W
35.00N


Stage IV
24hr QPE Accumulation
Valid Period:
05/01/2010 12:00:00 - 05/02/2010 12:00:00 UTC
KHPX
KOHX
Precipitation [in]
Min=0.00,Avg=3.87,Max=11.79
No File Missing
0.01 0.10 0.25 0.50 0.75 1.0 1.5 2.0 2.5 3.0 4.0 5.0 6.0 8.0 10.0
37.00N
88.50W
84.58W
35.00N


Gauges vs QPE
24hr QPE: Q2 [Gauge Adj Rad]
Valid Period: 05/01/2010 12:00 - 05/02/2010 12:00 UTC
Gauge Groups: CoCoRah
Scatter Plot:
Total Gauges In Region: 168
Total With Non-Missing QPE: 168
[9 Pts Exceed Current Plot Range]
QPE Amounts [in]
Gauge Amounts [in]
Summary/Stats:
Gauge [in] QPE [in]
Max: 13.30 12.52
Avg: 4.52 4.42
Min: 0.22 0.11
Gauge Group Counts
[A] BT Gauge/BT QPE: 5
[B] BT Gauge/AT QPE: 2
[C] AT Gauge/BT QPE: 0
[D] AT Gauge/AT QPE: 161
AT/BT = Above/Below Threshold
Threshold: 0.10 in
Group[B+C+D] Group[D]
Bias: 0.99 0.99
Corr Coeff: 0.93 0.93
RMSE: 0.98 0.99
Region:
37.00N
88.50W
84.58W
35.00N
Mask: none
Verif Mode: 1pt

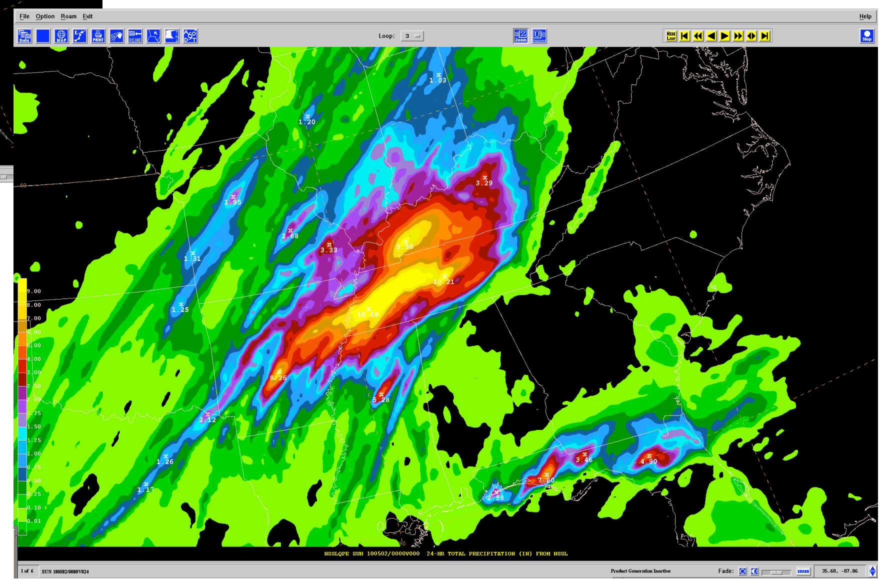

Gauges vs QPE
24hr QPE: Stage IV
Valid Period: 05/01/2010 12:00 - 05/02/2010 12:00 UTC
Gauge Groups: CoCoRah
Scatter Plot:
Total Gauges In Region: 168
Total With Non-Missing QPE: 168
[5 Pts Exceed Current Plot Range]
QPE Amounts [in]
Gauge Amounts [in]
Summary/Stats:
Gauge [in] QPE [in]
Max: 13.30 10.65
Avg: 4.52 4.31
Min: 0.22 0.20
Gauge Group Counts
[A] BT Gauge/BT QPE: 6
[B] BT Gauge/AT QPE: 1
[C] AT Gauge/BT QPE: 0
[D] AT Gauge/AT QPE: 161
AT/BT = Above/Below Threshold
Threshold: 0.10 in
Group[B+C+D] Group[D]
Bias: 0.96 0.96
Corr Coeff: 0.93 0.92
RMSE: 1.01 1.01
Region:
37.00N
88.50W
84.58W
35.00N
Mask: none
Verif Mode: 1pt

NSSL WRF QPF



24-hr QPF 4-km Hi-res WRF-ARW Valid 00z 02May2010

NSSL QPE 24-hr Precipitation Estimate Valid 00z 02May2010



Q2 Future Research Activities

Q2 ‘best science’ infusion into NWS operations

Integration of dual polarization moments and techniques into the Q2 framework

Seamless integration of radar systems and radar networks - forward compatibility

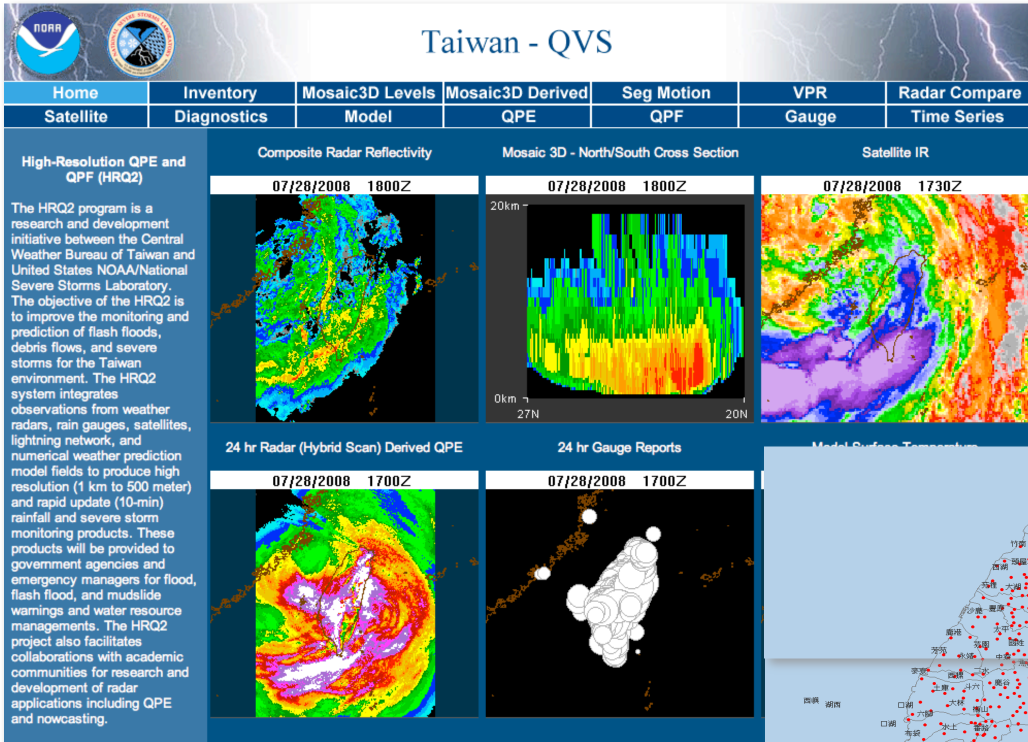
Higher resolution in both space and time to address the urban FFs

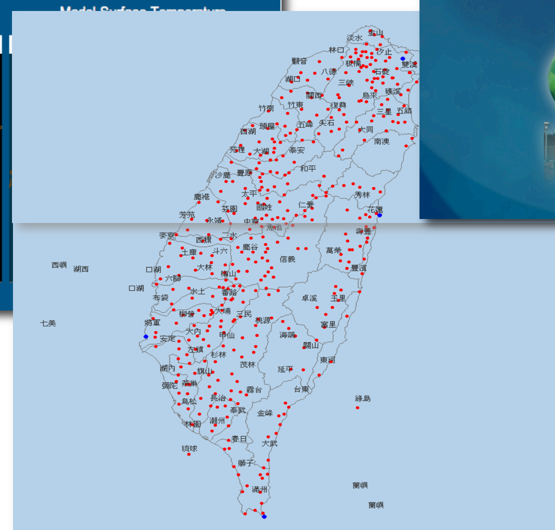
Maintain and support Q2 as a national hydromet testbed for ‘real time’ technique development and product evaluation

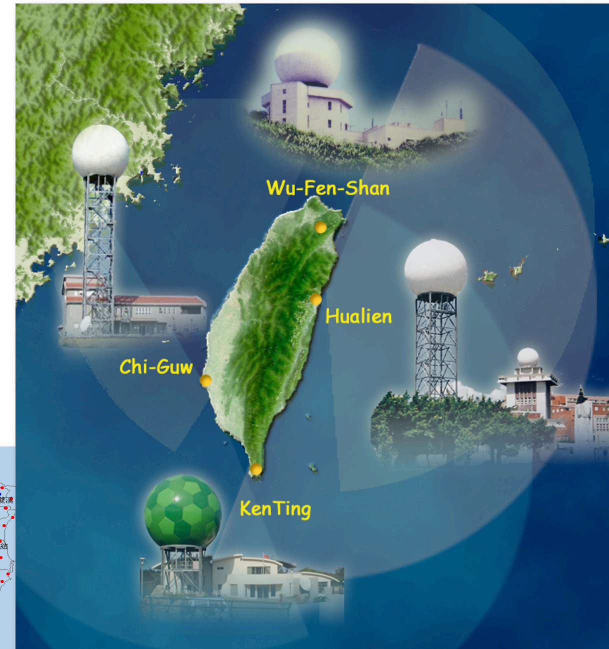
Transition MRMS system and Q2 to NCEP (OSIP Gate 3/NextGen – waiting for funding)

International Collaborations

Central Weather Bureau
Taipei, Taiwan







471 Gauges
10 Minutes

High Quality

Taiwan warm season hydrometerological challenges are possibly the most difficult in the world.

Thank you !